Smart and agile 88 W Yb-fiber frequency comb laser

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Optical frequency comb lasers are used in many applications in science and technology. For most applications output power levels around a few watts are sufficient. However, some applications require significant higher power ranges, for example to drive extreme nonlinear processes in gases for extreme ultraviolet (XUV) frequency comb generation. Although, efficient power scaling of fiber-frequency combs to the 100 W level was demonstrated more than 10 years ago [1] and recently kW average power levels on CEP (carrier-envelope phase) stabilized fiber laser systems were achieved [2], there are still only a few high-power frequency comb systems reported to date [3], typically requiring a team of experienced laser scientists for operation.

Here we demonstrate the first steps towards closing the gap in versatility and user-friendliness of high-power optical frequency comb systems by introducing digital controls for pulse shaping, dispersion management and comb-stabilization on a 65 MHz Yb-fiber frequency comb system delivering more than 88 W output power.

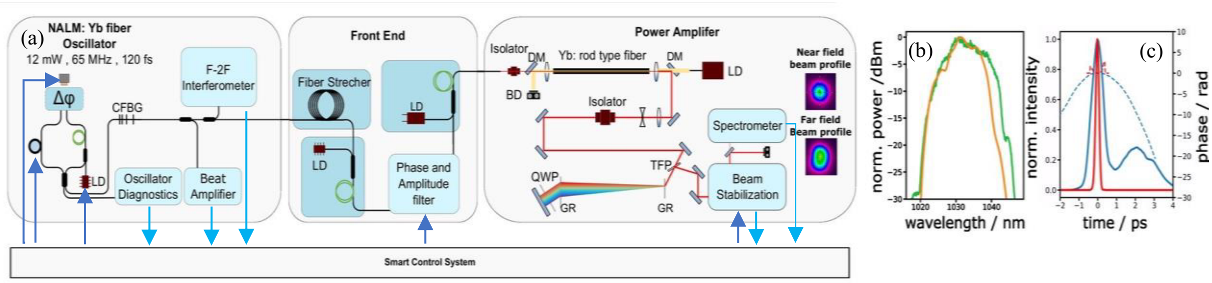

Fig. 1 (a) Schematic of the experimental set-up. LD: Laser diode, TFP: Thin Film Polarizer, GR: Grating, CFBG: chirped fiber Bragg grating, BD: beam dump, QWP: quarter wave plate; (b) measured spectral intensity (green) by optical spectrum analyzer (OSA) and retrieved spectral intensity (orange) by frequency resolved optical gating (FROG); (c) retrieved temporal intensity and phase (FROG) before (blue) and after (red) optimizing the phase and amplitude filter.

The laser system shown in Fig. 1(a) is seeded by 65 MHz compact and low noise Yb:fiber nonlinear amplifying loop mirror (NALM) oscillator [4]. For dispersion management, we use a combination of passive fiber and a frequency-domain phase and amplitude filter (FINISAR 1000A) which is sandwiched between two Yb-doped fiber amplifier stages. We employ an Yb-doped rod type fiber (NKT Photonics) for the last gain stage to reach more than 110 W output power before the compression. Brain of the laser system are its digital controls: The entire laser-system is operated by the control system DOOCS developed for DESY's X-ray light sources [5]. For comb stabilization the phase-locked loops are digitally implemented via field-programmable gate arrays (FPGAs) and driven by the open-source python package pyrpl [6]. We also digitally control the frequency-domain phase and amplitude filter. It is not only used for versatile dispersion control to reach the shortest output pulse Fig. 1(c), but also for optimization of the output pulse phase and amplitude for controlled center wavelength shifting in nonlinear multipass cavities, translating our Yb-comb into a wavelength-tunable source covering a spectral range of 1000 nm – 1060 nm [7].

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